Development and Validation of 3-D Model for Fluid Structure Interactions in Blast Wave Loading

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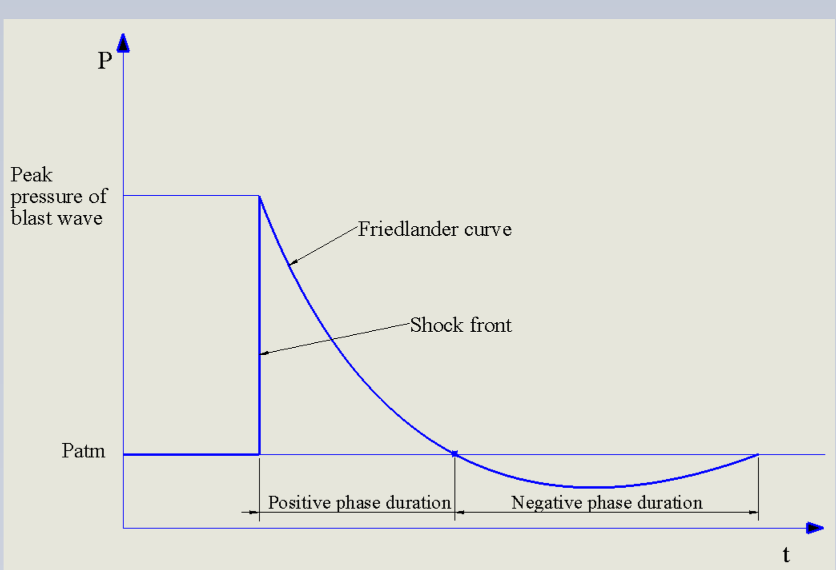
Introduction

Blast injury is a rising area of interest to researchers due to the steady presence of military personnel around the world. There are three types of blast injuries.

1. Primary injuries are due to overpressure.
2. Secondary injuries are due to shrapnel.
3. Tertiary injuries are due to a person's body being accelerated into a rigid object.

The pressure wave that radiates outward after an explosion is described by the Friedlander Wave shown below.



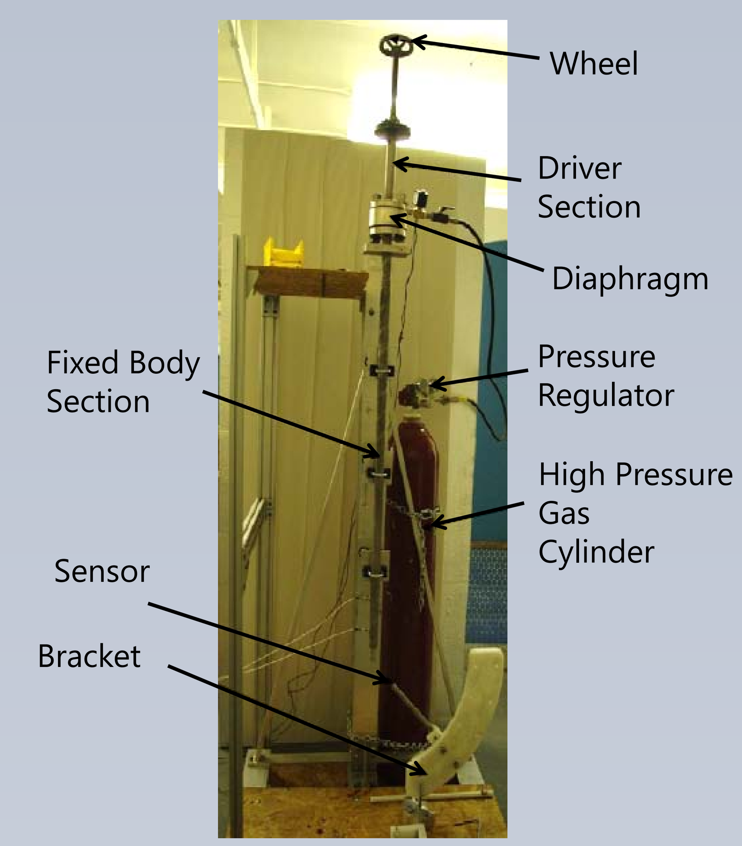
Primary loading has been shown to be a cause of traumatic brain injury (TBI). The purpose behind this research is to uncover the critical thresholds of pressure that would lead to TBI.

Motivation

The rise of primary blast injuries in the military is nothing new. In 1999, primary blast loading accounted for 50% of explosion injuries in the military

Methodology

A blast wave can be generated in a laboratory with a shock tube. Below is the shock tube used in Dr. Monson's lab.



1. Compressed nitrogen is fed into the driver section
2. The diaphragm breaks and releases a shock wave down the length of the tube.
3. Expansion waves reflect off the back of the tube, catch up to the shock wave and degrade it creating a blast wave.
4. Rats are used to gauge injury thresholds

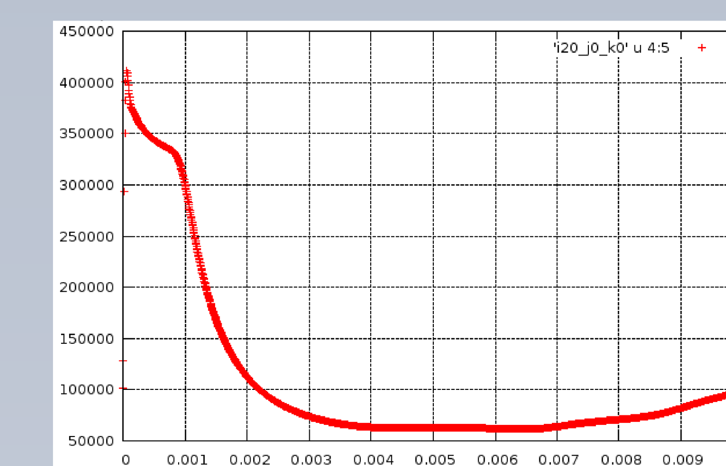
Computationally models allow for predictions and changing parameters not easily changed in a laboratory. A previous student created a computational model of the shock tube using an explosion software called UINTAH, which was developed at the University of Utah. An input file is fed into the software describing the boundary conditions and key parameters.

This model was made in 1, 2 and 3 dimensions. The 1-D model can be run on one machine while the 2-D and 3-D models require the Center for High Performance Computing (CHPC).

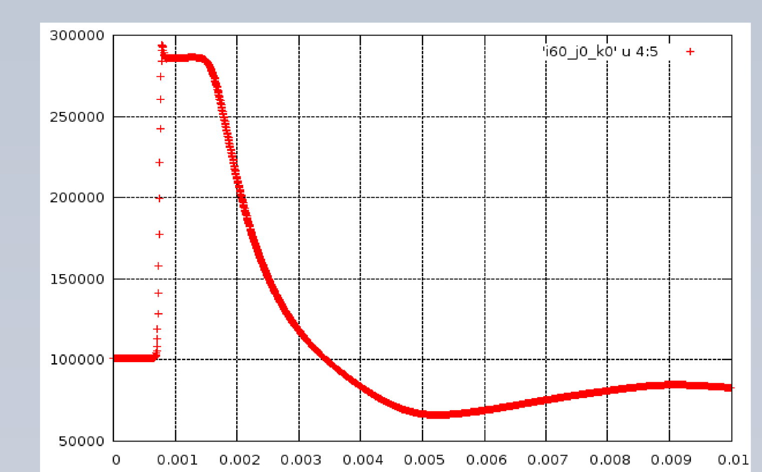
The first step of the research was to become familiar with the 1-D input file and how to execute the code to generate the same results. The code is run in Linux and so there was a learning curve to use the operating system commands as well. The 1-D model was successfully run and the results are shown above.

Results

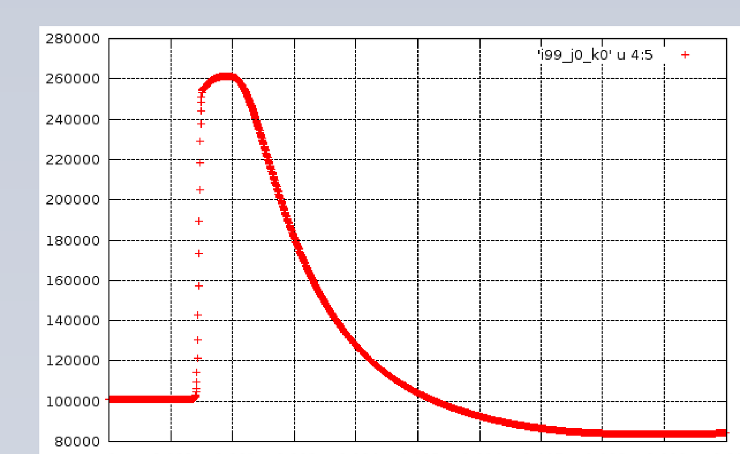
Below, are three pressure plots taken at the beginning middle and end of the 1-D shock tube model.



The beginning of the tube sees the highest overpressure of 400kPa and a full negative pressure region.



The middle of the tube sees about 280kPa. This is due to the losses through the fluid structure interaction and due to wave expansion.



By the end of the tube, the pressure has dropped to 260kPa. This is still above the lab results of 140kPa. This difference is due to the 1-D model not predicting 3-D losses.

Conclusion

The 1-D model was successfully reconstructed with similar results. The next step is to use the Center for High Performance Computing (CHPC) to model the 2-D and 3-D tubes. After which, another obstacle will be placed outside the tube to capture the fluid structure interactions with the blast wave. This obstacle will eventually be developed into brain tissue. This model will allow researchers to understand how a blast wave interacts with the brain.